ready published in the January number of the *Annals and Magazine of Natural History.* This animal has a jointed stem and an oval zoœcium. When it first came on board I thought I had discovered a living Cystoid or Blastoid, as its shape was almost the same as that of some genera belonging to these types so familiar to the geologist, but now long extinct. In this, however, I was disappointed, although abundantly rewarded in finding a new genus of Polyozoa, Astrorhiza.

The dredge also brought up great masses of a Retepora, which is called coral by the sailors in this locality, and are sometimes larger than a man's head. Innumerable other lower animals people these depths.

A fair but light wind brought us back to the wharf of Santa Barbara early in the evening of the day we left Prisoner's Harbor. We heard the sound of the evening bells of the Mission Church come down the side of the mesa, and as we threw our anchor the bright electric light of the city welcomed us home. The next morning a haze covered the base of the island of the Holy Cross, out of which rose the peak of Ragged Mountain like a monster from the sea. As the day wore on the fog lifted, and the soft African haze which gives the great charm to Santa Barbara ocean scenery took its place and the form of the beautiful island came out in all its extent, its outlines softened by the distance, and its dark cañons alternating with projecting headlands indistinguishable over the stretch of water which separates it from the mainland. The same island stands out clear in the beautiful light, unchanged since Cabrillo sailed up the channel for the first time fifty years after Columbus discovered the New World.

THE VEGETATION OF HOT SPRINGS.

BY WALTER HARVEY WEED.

THE vegetation of hot waters, though lowly organized and composed of obscure forms, is of considerable interest to all students of Nature, since the plants occur in very highly heated and mineralized waters under conditions that are fatal

to all other forms of life. The ability possessed by the vegetation found in such waters to withstand such extreme and adverse conditions of environment shows the possible existence of this form of life during the early history of our globe, when the crust of the earth is supposed to have been covered with hot and highly mineralized waters. Such plants may thus represent the earliest links in the chain of evolution.

While the mosses Hypnum and Sphagnum have been found in warm waters (90°–100° Fahr.), the vegetable life of hot water consists wholly of fresh water algæ. Such plants are usually less striking in appearance than the sea-weeds, but assume most curious and interesting forms when subjected to the peculiar conditions that prevail in hot springs.

It has long been known that algæ occur in hot waters, and the descriptions of hot springs given by travelers often contain allusions to the presence of bright green "confervæ" living in the hot pools and streams. Algæ are common also in the hot waste waters flowing from many mills, the brilliant green growths lining the conduits. Where the plants present in thermal waters are of this color, their vegetable nature seems to have been readily recognized; but there is good reason to believe that the existence of algæ of other colors, particularly the pink, yellow and red, forms so common in the Yellowstone waters, have been overlooked or mistaken for deposits of purely mineral matter. That such is the case is not at all surprising, for the plants often surround themselves with a hyaline gelatinous envelope, or are encrusted and hidden by mineral matter extracted from, or deposited by, the hot waters, and sometimes obscuring the plant growth so completely that the organic nature of the substance is scarcely recognizable even by an algologist. Thus the Beggiatoæ, the characteristic vegetation of sulphur springs, were long considered a lifeless organic slime. Their silky threads are often completely hidden by grains of sulphur, or entombed beneath a deposit of gypsum.

The vegetable life of hot calcareous waters is very often

shrouded in carbonate of lime, the growing tips alone projecting out of the stony mass. In ferruginous and in siliceous waters the mineral matter of the waters obscures and hides the vegetable filaments. Unfortunately, those who have studied the flora of hot springs have rarely published sufficient detail concerning the habitat of the species described to enable one to follow up this interesting feature of the subject, while the algæ have been studied rather from a systematic than a broad biological standpoint.

In reviewing the literature bearing upon the subject, I have found that vegetable life is a common accompaniment of thermal springs, and as widely distributed as the springs themselves. At the noted warm springs of Carlsbad, where the algous life has been studied by several botanists, there is a great variety of species, but the limiting temperature appears to be 130° Fahr.[1]

Sir William Hooker[2] and Baring Gould[3] both mention the occurrence of crimson algæ in the hot geyser waters of Iceland, and Hochstetter[4] and other writers[5] describe slimy confervoid plants lining the bottoms of hot pools and streams in New Zealand, the highest temperature at which such growths have been observed being 153° Fahr.

In the hot springs of the Azores, Mosely found algæ growing in water whose temperature was between 149° Fahr. and 156° Fahr., and on areas splashed by almost boiling water. At the volcano of Camiguin no vegetation was found until the water had cooled down to 113.5° Fahr.[6] In the Himalayan hot springs Dr. Hooker found a luxuriant growth of Leptothrix at 168°Fahr. and below.[7] Several other references were

[1] Abhandl. Schles. Gesell. 1862. Heft II.

[2] Journal of a Tour in Iceland. Vol. 1., p. 160.

[3] Iceland: Its Scenes and Sagas.

[4] Reise der Oe Frigate Novara.

[5] Skey. Trans. N. Z. Inst. Vol. X., p. 433. Spencer. Trans. N. Z. Inst. Vol. XV., p. 302.

[6] Journ. Linn. Soc. (Botany.) Vol. XIV., p. 328.

[7] Himalayan Travels. Jos. Dalton Hooker. Vol. I., pp. 27, 379.

found proving the abundance of algæ in waters of 150° Fahr. or below. The highest temperature at which these growths have been found is that observed by Professor Brewer at Pluton Creek, California, where algæ were found at 200° Fahr.[1]

In the hot springs of Ischia no life was observed above 185° Fahr.,[2] and this appears to be the limiting temperature in the hot waters of the Yellowstone National Park.

A comparison of the species found in hot springs shows that they are limited to a few groups. Although the true Confervoideæ and the Protococcoideæ are represented in gatherings from hot waters, the Oscillatorieæ form the most characteristic vegetation of hot springs, species of Oscillaria and Hypheothrix being very common. *Hypheothrix laminosa* (a species variously known under a number of synonyms) has been found in New Zealand, Java, St. Paul, Camiguin, Iceland (?) and the Yellowstone Park, being very common at the last locality.

Desmids have been found in the hot waters of the Azores, three species of Pediastrum being described, and Corda figures and describes Desmids from the Carlsbad hot springs. The Diatomaceæ do not appear to be very abundant in hot waters. Dr. Jas. Blake found a number of species at 140° Fahr. in the hot springs of Nevada, and nine species were found by Berkeley in the gatherings from Thibet. They are comparatively rare in the Yellowstone gatherings from hot water, but very abundant in the cooled waters from the springs.

The examinations made by Mr. W. Archer of the gatherings of algæ from the hot springs of the Azores show that certain species were identical with forms common in cold surface waters in Great Britain. Prof. W. G. Farlow, of Harvard, who is studying a series of specimens collected by the writer from the hot waters of the Yellowstone Park, informs me that here also cold water forms are found, but modified by their conditions of environment. It is hoped the material in Professor

[1] Amer. Journn. Sci. (2.) XLVI., p. 31.

[2] Sachs, in *Flora.* 1864.

Farlow's hands will yield important information concerning the morphology of the species.

In a study of the hot springs and the geyser phenomena of the Yellowstone National Park, carried on in connection with my geological work in that region, I was surprised to find an abundant algous vegetation in the hot springs even at very high temperatures. It has been found by an examination of the hot springs of the region, of which nearly 3,500 have been individually and carefully noted, that algæ are almost universally present either in the springs themselves or in the streams flowing from them. The only exceptions to this are the mud bowls, and even here algæ are often found on the borders where kept moist by steam. This widespread occurrence implies that algæ can exist under a very great diversity of conditions. The springs examined differ greatly in the chemical composition of their waters, and include carbonated, calcareous and siliceous alkaline waters, and also those acid with hydrochloric or with sulphuric acids. The algæ also occur under equally diverse thermometric and hygrometric conditions; they have been found at all temperatures up to 185° Fahr., though from 160° to 185° they have thus far been observed only in running streams.

It is difficult to give a general description of the vegetable life of hot springs which shall be brief, and yet convey any idea of the beauty and the varied forms of these growths. The vegetation of the acid waters (with free HCl or H_2SO_4) is seldom a conspicuous feature of the springs. But in the alkaline waters that characterize the geyser basins, and in the carbonated, calcareous waters of the mammoth hot springs, the case is otherwise, and the red and yellow tints of the algæ combine with the weird whiteness of the sinter and the varied blue and green of the hot water to form a scene that is, without doubt, one of the most beautiful as well as one of the strangest sights in the world. Those who have been so fortunate as to have seen the hot water fountains of the Yellowstone will be sure to remember the delicate and charming tints that characterize the basins about Old Faithful and many other geysers

of the upper basin, as well as the bright reds and yellows of Specimen Lake and the Orange Pool.

Early in the study which was made of these springs, it was noticed that the color of the vegetation was, in a degree, dependent upon, or related to, the temperature of the water. This is well illustrated by the occurrence of *Hypheothrix laminosa*, whose delicate filaments wave in the stream draining the Black Sand, where the following relation of color to temperature was observed:

White—185°.

Flesh pink—181°, becoming browner as the temperature falls.

Pale yellow—164°.

Yellow green—155°.

Emerald green—135°–140°.

Dark green—130°. These colors merging, of course, into one another, but being very prominent at the temperature given. Other growths are:

Orange—125°.

Red—110°.

Cedar brown—90°.

An examination of the growths forming the first series by Professor Farlow proves that the flesh-colored and white growth, occurring at 180°–185°, shows but traces of algæ filaments in amorphous matter. At 164° the structure was more decidedly filamentary and the color light yellow. The bright green forms at 155° were in a better condition for study, and the dark green filaments at 130° were in good condition. *Hypheothrix laminosa* probably attains its fullest and most perfect development in these waters between 130° and 155° Fahr.

In those clear bowls of hot but never boiling water called *laugs*, the algæ often form a leathery sheet lining the sides and bottom of the pools. Each sheet consists of a great number of thin, membranous layers aggregating one-fourth to one-half inch in thickness; the under layers are a rich tomato red, and the surface covered with a thin, incoherent

fuzz of green, through which the red tint beneath shows and produces an olive tone.

The algæ tinting the hotter *laugs*, with temperatures of 140° to 160° Fahr., are bright yellow, and form a loose, velvety nap on the soft, siliceous sediment.

Where the overflow from a spring is constant in volume the channels are rapidly filled, choked and dammed back by masses of red and green algous jelly from one-half to five inches thick. This form of growth and the process of sinter formation has been already described elsewhere.[1] The channels carrying off the periodic discharge of the geysers are also brilliantly tinted by algæ, but modified by the deposit of silica. The channels of Old Faithful are a brilliant gamboge yellow near the geyser, merging into orange, which changes abruptly into brown, while farther away the growth is cedar red.

In these cases the plants form a thin, slippery coating upon the siliceous sinter, and is much encrusted by silica. Where from any cause the algæ growing in these channels are deprived of their supply of water, the siliceous jelly enveloping the growth is rapidly dried, and becomes hard, white and opaque, effectually concealing the algæ. Where channels are lined with a membranous growth, this shrivels up into curious convoluted forms, or into papyrus-like rolls. In fact, whatever the nature of the algæ present in the siliceous waters, all appearance of vegetable life is soon lost on drying, owing to the hardening of the silica. In calcareous waters the change is none the less complete, and the green or red growth rapidly bleaches out and becomes all but invisible to the casual observer in the deposit. The filaments may, however, be freed from the lime by the aid of acid.

[1] Amer. Journ. Sci. May, 1889.